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APPLICATION FOR U.S. LETTERS PATENT

Title:

DIE ATTACH CURING METHOD FOR SEMICONDUCTOR DEVICE

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DIE ATTACH CURING METHOD FOR SEMICONDUCTOR DEVICE

FIELD OF THE INVENTION

5 The present invention generally relates to semiconductor device fabrication. More particularly, the present invention relates to the curing of an adhesive material used in affixing solder masks to semiconductor chips.

BACKGROUND OF THE INVENTION

10 Some conventional semiconductor devices include chips having a solder mask and printed or screened-on conductive traces for wirebonding to a ball grid array (BGA). Generally, the solder mask is affixed to the chip by an adhesive material. Typically, the adhesive material is applied to the chip and allowed to cure prior to deposition of the solder mask. Currently utilized adhesive materials cure at a temperature in excess of 150°C.

15 Most solder masks are formed from a liquid photoimageable material. Two popular solvents used in forming liquid photoimageable solder masks are diethylene glycol monoethyl ether acetate (DGMEA) and dipropylene glycol monoethyl ether (DGME). Often a heavy aromatic naphtha also is used as a photoinitiator. All of these materials boil at relatively high temperatures. Specifically, DGMEA boils at 219°C, DGME boils at 90°C, and naphtha boils at between 80° and 220°C.

20 Some currently used fabrication methods cure the adhesive material along with the solder mask. During such methods, a cure of about one hour at 150°C of the liquid photoimageable solder mask is carried out. Such a cure serves to drive the low temperature volatile components of the solder mask, i.e., from the DGMEA and/or

DGME, out, leaving behind the higher temperature volatiles to outgas later when the temperature of the device in operation reaches a sufficient outgassing temperature.

5 Since the cure time and temperature are insufficient to cure the adhesive material, later outgassing may induce voids in the adhesive material. Voids are capable of entrapping moisture, causing the semiconductor package to fail an environmental test. Further, outgassing contaminates the bond pads, resulting in a low bond yield. In addition, curing at high temperatures creates thermal stresses between the adhesive material and the die which are particularly problematic for large and/or thin semiconductor device packages.

10 There exists a need for a curing methodology which inhibits the effects of outgassing on adhesive material, thereby reducing voiding and the collection of moisture within the adhesive material, as well as which reduces thermal stress on the device package and contamination of the bond pads.

SUMMARY OF THE INVENTION

15 The present invention provides a semiconductor device having a solder mask, a die and an adhesive layer affixing the die to the solder mask. The adhesive layer is cured at a temperature below about 100°C.

20 The present invention also provides a semiconductor device having a solder mask, a die, electrical contacts on the solder mask and the die, each contact on the die being wire bonded to a respective contact on the mask, and an adhesive layer affixing the die to the solder mask. The adhesive layer is cured at a temperature between about

20°C and about 50° higher than a glassy temperature of the adhesive layer and the curing temperature is below about 100°C.

The present invention further provides a semiconductor package including a chip, a solder mask affixed to a die by an adhesive layer which is cured at a temperature below about 100°C, the die being electrically connected to the chip, and a mold 5 encapsulating the chip, solder mask and die.

The present invention further provides a method of forming a semiconductor device. The method includes the steps of affixing a solder mask to a semiconductor die with an adhesive layer, and curing the adhesive layer by exposing the adhesive layer to a temperature no greater than 100°C. 10

These and other advantages and features of the invention will be more readily understood from the following detailed description of the invention which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 FIG. 1 is a cross-sectional view of a conventionally fabricated semiconductor chip on a printed circuit board.

FIG. 2 is a cross-sectional view of a semiconductor chip on a printed circuit board fabricated in accordance with an embodiment of the invention.

20 FIG. 3 is a graph of the change in the modulus of elasticity of an adhesive material over a temperature range.

5 FIG. 4 is a graph of the change in the coefficient of thermal expansion of an adhesive material over a temperature range.

10 FIG. 5 is a graph depicting the wire bond pull force of an 80°C cured adhesive material versus a 125°C cured adhesive material.

15 FIG. 6 is a graph depicting radii of curvature for various adhesive materials at various temperatures and curing times.

20 FIG. 7 illustrates a method of forming a semiconductor package in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25 FIG. 1 illustrates a conventionally fabricated semiconductor device 10, which includes a die 12 affixed to a solder mask 18 by an adhesive layer 14. The die 12 has contacts 20 in connection with contacts 22 on the solder mask 18. Specifically, each contact 20 is connected with a respective contact 22 through a wire bond 28. The solder mask 18 is affixed to a printed circuit board 40 or other substrate. The solder mask 18 contains DGMEA or DGME, or other materials. Further, a heavy aromatic naphtha may be used as a photoinitiator.

30 During the high temperature die attach, adhesive curing, high temperature volatiles outgas from the solder mask 18 and/or the printed circuit board 40, forming voids 16 in the adhesive layer 14. As noted above, voids can trap moisture, causing the device 10 to fail an environmental test. Further, the outgassing may contaminate the contacts 20, 22, thereby decreasing the likelihood of a good bond therebetween.

The present invention obviates the problems caused by high temperature curing of the solder mask 18 by initially low temperature curing the adhesive layer.

FIG. 2 shows a semiconductor device 100 formed in accordance with the present invention. The die 12 is affixed to the solder mask 18 by an adhesive layer 114. The layer 114 is subjected to a low temperature cure, for example, below 100°C, for a period of time to sufficiently solidify the adhesive layer 114, rendering it more impervious to the effects of outgassing.

Referring now to FIGS. 3-4, there is a correlation between both the Young's Modulus (E) and the coefficient of thermal expansion (CTE). Specifically, there is a limited temperature range at which a material changes from a flexible/pliable state to a solid. At that same limited temperature range, a material's CTE is changed. This limited temperature range is called the glassy temperature T_g . The adhesive layer 14 (FIG. 1) is formulated such that its cure temperature is greater than or equal to its glassy temperature T_g , and since it cures at about 150°C, its T_g is equal to or less than about 150°C.

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The adhesive layer 114 is formulated to cure at a temperature below 100°C. A preferred formulation of the adhesive layer 114 includes one or more components which cure at or below 100°C. One such component is a resin bismaleimide. The bismaleimide may be the sole component in the layer 114 or it may be present in the adhesive layer 114 as a component. The adhesive layer 114 may include initiators which act as a catalyst to begin the curing at a lower temperature. One such initiator is peroxide, which upon being heated to a temperature below 100°C, releases free radicals. The free radicals start the chain polymerization.

Bismaleimide has a glassy temperature T_g of between about 5°C and about 10°C. To completely cure a resin, i.e., to fully cross-link the resin, a temperature of about 50°C above the glassy temperature T_g is required. Thus, an adhesive layer 114 formed of bismaleimide will cure at a temperature of about 70°C. A higher 5 temperature would accelerate the curing process. Curing at temperatures below 100°C reduces the stresses between the adhesive layer 114 and the die 12 and strengthens the adhesive layer 114 against voids 16 caused by outgassing. Further, a low temperature cure reduces the release of volatiles which can contaminate the contacts 20, 22, and thus a low temperature cure will provide a cleaner wire bonding site at the contacts 20, 10 22.

One test to determine the viability of low temperature curing is to measure the wire pull force. Measuring the pull force allows one to ascertain which adhesives that are cured at low temperature perform similarly to adhesives which are cured at high temperatures. Typically, one would expect a lower force with a non-fully cured adhesive. Referring to FIG. 5, a pair of cured adhesives, B170 and D170, were stress tested. D170 is a die adhesive cured for four hours at 80°C, and B170 is a die adhesive cured at 125° for one hour (manufacturer's suggested cure profile). The force required 15 to pull a wire bond of D170 free at 170°C is approximately 6.75 grams, which measures favorably to the 5.75 grams for the B170 adhesive. This result indicates that a low temperature cure (below 100°C) does not affect the mechanical strength of the 20 material.

The stress of the adhesive may be determined by measuring the radius of curvature (ROC) measurement. The higher the stress of the adhesive, the lower the

ROC. FIG. 6 illustrates the radius of curvature (ROC) of an adhesive material over a variety of conditions. Table 1 illustrates the various conditions.

TABLE 1

| <u>Reference</u> | <u>Condition</u> |
|------------------|--|
| A | cured at 125° for one hour. |
| A125 | cured at 125° for one hour and wire bonded at 125°C. |
| A170 | cured at 125° for one hour and wire bonded at 170°C. |
| C | cured at 80° for four hours. |
| C125 | cured at 80°C for four hours and wire bonded at 125°C. |
| C170 | cured at 80° for four hours and wire bonded at 170°C. |
| G1 | cured at 150°C for twenty minutes. |
| G2 | cured at 150°C for forty minutes. |
| G3 | cured at 150°C for one hour. |
| G4 | cured at 150°C for two hours. |

As indicated in FIG. 6, the low temperature cured adhesive material 114, denoted as C, C125 and C170, shows a higher radius of curvature than the adhesive materials which were high temperature cured. As noted above, the higher the ROC the lower the stress of the adhesive

FIG. 6 also indicates that as long as the adhesion is adequate, the curing of the adhesive layer 114 does not need to be complete. More curing can be accomplished at the following processes: wire bonding, encapsulation, solder reflow, and testing. It has been determined that the adhesive layer 114 subjected to a fifty percent cure exhibits sufficient adhesive strength to pass the package assembly process.

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Referring to FIG. 7, next will be described a method for fabricating a semiconductor device package. The initial step 200 is to affix the die 12 to the solder mask 18 with the adhesive material 114. Then, the adhesive material 114 undergoes a low temperature cure at step 205. As indicated above, the low temperature cure is at a temperature below 100°C. The contacts 20 are electrically connected by the wire bonds 28 to the contacts 22 at step 210. The entire assemblage is encapsulated in a mold at step 215. The molding process is typically at a high temperature, for example, greater than or equal to about 180°C. An optional post mold cure is then provided at step 220. The post mold cure is typically at about 175° for about four hours.

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If the adhesive material 114 is not completely cured during the low temperature cure step 205, it will become so during the subsequent heating steps 210, 220. High temperature curing, as noted above, may introduce high thermal stress. Nonetheless, the amount of thermal stress imparted to the adhesive material 114 is reduced since at least fifty percent of the adhesive material 114 is cured at a low temperature.

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The present invention provides an adhesive material which is low temperature cured, thus reducing thermal stresses and the formation of voids. The present invention further provides a method for making a semiconductor device including such an adhesive material.

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While the invention has been described in detail in connection with the preferred embodiments known at the time, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or